Study on the stream enthalpy generated during dressing of the grinding wheel

Badania entalpii strugi tworzącej się podczas obciągania ściernicy

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RYSZARD DĘBKOWSKI
ANDRZEJ ROSIAK *

In the article the method of measuring the stream enthalpy of a particle formed during dry-dressing using a single point diamond dresser is described. In the described method, a Peltier module was used as a heat sensor. The authors presented basic information on the construction, principles of measurement with Peltier module and the way to calibrate it as well as the results of the studies on the enthalpy of the stream formed during the dressing of vitrified alumina grinding wheel. Conducted studies were performed with different feed and depth settings.
KEYWORDS: single point diamond dresser, heat flux, temperature

During dressing of the grinding wheels, a considerable amount of heat is generated, which significantly contributes to accelerating the wear of the diamond tip by activating the oxidation and graphitization processes and causing mechanical damage to the crystal due to thermal fatigue or hardening [1–4]. The amount of heat generated depends on many factors, including geometry of the diamond tip, value of the adjustability of the dressing process, and physicochemical properties of the grinding wheel.

In the case of a dressing without the use of a cooling fluid, the heat generated in the diamond contact area with the grinding wheel is dispersed through [2]:
- conductivity (in the volume of grain further by the solder to the body of the dresser, the holder and further to the grinder body, and also via the CPS of the grinding wheel to its body, luminaire, etc.),
- convection (forced circulation of the rotating air layer with the grinding wheel),
- thermal radiation to bodies from the proximal and distant surroundings,
- dust of crushed grinding wheel.

This paper presents an assessment of the amount of heat carried by particles of the stream formed during dressing of the wheel under dry dressing conditions.

Measurement method

For the measurement of the enthalpy of the stream of particles, Peltier module operating in repeat mode of the thermoelectric element, was used.

In the Peltier module, there are serially connected semiconductor cells between two ceramic plates with excellent electrical insulation and good thermal conductivity.

* Dr inż. Ryszard Dębkowski (ryszard.debkowski@p.lodz.pl), dr inż. Andrzej Rosiak (andrzej.rosiak@p.lodz.pl) – Politechnika Łódzka

If the ceramic tiles have different temperatures, the voltage on the module terminals is proportional to the difference in temperature. In the application described, Peltier module must be placed at a predetermined angle *α* in the path of movement of the spray, a short distance from the place of its creation. Stream particles, when reflecting/slipping/depositing on the surface of the ceramic plate of the module, transmit heat, which results in the appearance of electrical voltage on its terminals (fig. 1).

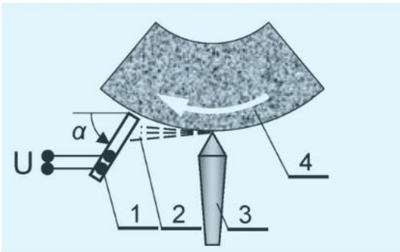

Fig. 1. Diagram of measurement method (*1* – Peltier module, *2* – stream, *3* – collar, *4* – wheel)

The approximate value of the voltage generated at the terminals of the module is given by:

$$U = a_m(T_h - T_c) \quad (1)$$

where: a_m – mean value of the Seebeck factor; T_h – temperature of the "hot" side of the module; T_c – temperature of the "cold" side of the module.

When the enthalpy of the stream of particles is defined in this way, it should be noted that the measurement will have an error resulting from the unknown:
- amount of heat generated by friction of the particle stream with the surface of the plate,
- amount of heat dissipated when the stream travels on the path between the diamond tip and the plate surface of the module,
- amount of energy accumulated by the dust that has not been transferred to the module.

In order to implement the measuring principle described, a support structure for the module 127 having a Peltier cell was constructed. Angular adjustment of the module was determined after a series of investigations, which evaluated the influence of the angle *α* (fig. 1) on the amount of voltage generated by the module attacked by a stream of blow products. After testing with different dressing conditions, it was found that the highest voltage values were recorded when the angle of deflection of the module plate from the direction of flow was *α* = 67°. This means that at this setting, the Peltier module exhibits the greatest heat transfer capability from the jet.

The path between the diamond tip and the module plate is covered by a thermally insulated channel. The cold side of the module was equipped with a heat sink, which was cooled by the swirling wheel air flow and the dust extraction operation near the dressing area. Thermoelectric voltage is recorded by computers with analog-to-digital and application program LabView.

Experimental studies

Experimental studies were divided into two stages:

- calibration of the Peltier module – to determine the relationship between the quantity supplied to the heat module and the amount of generated voltage,
- essential tests – to evaluate the value of the enthalpy of the stream depending on the dressing parameters.

■ **Calibration of the Peltier module.** The purpose of the calibration was to determine the voltage dependence on the terminals of the module on the amount of heat absorbed by the ceramic plate of its liner. The development of such characteristics required to carry out studies, in which is provided a control unit provided to the stream. As the delivery system a known amount of energy (the balance system) was used in a thermally insulated copper bar with a known heat capacity, with the possibility of current control its temperature. The bar size was chosen based on the basic characteristics of the module used and the values of the voltages obtained in the preliminary tests not described here. The cylindrical surface of the bar is covered with thermal insulation to limit the penetration of heat into the environment.

The tests consisted of periodic (or continuous) contact of the face heated up to different bar temperatures with the surface of the ceramic plate of the module and continuous recording of its temperature and thermoelectric voltage generated by the module. Bar temperature measurement was performed using a copper-constantan thermocouple placed on its cylindrical surface in the immediate vicinity of the face being in contact with the module.

Fig. 2 shows a diagram of the test realization method and exemplary graphs of the obtained results of the bar temperature measurement and the thermoelectric voltage of the module. Recording of temperature and voltage was implemented digitally using two computer measuring tracks.

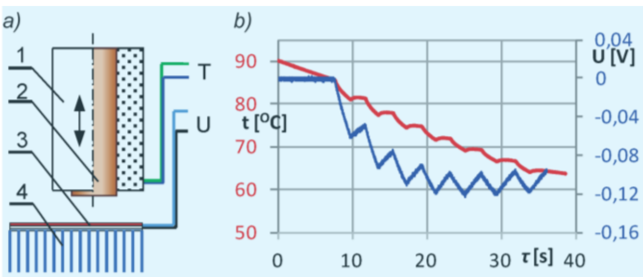

Fig. 2. Peltier module calibration system (*1* – thermal insulation, *2* – copper rod, *3* – Peltier module, *4* – heat sink) (*a*); change of the Peltier's thermoelectric voltage and the temperature of the balance system (*b*)

During contact with the module, the heat flux supplied by the Q_c balance system had two components:

- heat flux conducted to the ceramic plate Q_p module,
- heat wave penetrating into the environment Q_s, which can be written as:

$$\dot{Q}_c = \dot{Q}_p + \dot{Q}_s \tag{2}$$

To determine the amount of heat Q_p transferred to the Peltier module is significant from the point of view of calibrating the module. Heat is calculated by the method, the idea of which is shown in fig. 3*a*. This method does not take into account the occurring variation of the heat flux, but for short time periods, in which contact and heat transfer to the module were considered, these changes are limited.

Fig. 3*a* illustrates red line indicating temperature change of the balance bar during periodic contacting with the Peltier module, while the green lines – changing the temperature of the rod resulting from the heat rejection to the environment. The green lines were plotted on the basis of separate studies of free cooling of the balance sheet system.

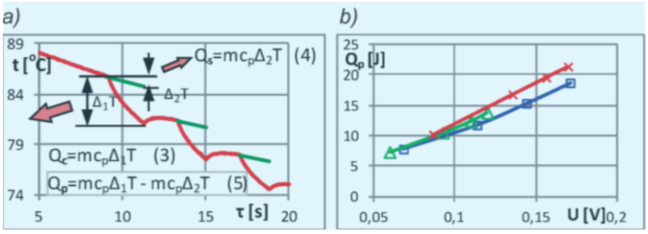

Fig. 3. Temperature diagram of the balance system during 3 control contacts (*a*); characteristics of the Peltier module: thermoelectric voltage – heat (*b*)

The total heat Q_c, which reflects the balance system during a single contact with the Peltier module, is described by the equation (3) shown in fig. 3*a*, while equation (4) indicates that part of the balance that was cast at that time to the Q_s. The symbols used in the equations are: m – mass of the copper rod; c_p – specific heat of copper; $\Delta_1 T$ – rod temperature change upon contact with a Peltier; $\Delta_2 T$ – change of temperature of the rod during free cooling. Difference between the energy values is the search of heat transmitted to the Peltier module – equation (5) in fig. 3*a*.

Since the initial temperature of contact of the rod with the module and beginning temperature of the free cooling are the same, the final calculation formula becomes:

$$Q_p = m \cdot c_p \cdot (T_{ks} - T_k) \tag{6}$$

where: T_k – bar temperature at the end of contact with the Peltier module; T_{ks} – final freezing temperature of the rod in the period equal to the contact of the rod with the module.

Based on the results of the tests and calculations, the characteristics of the dependence between the voltage on the terminals and the amount of thermal energy supplied to the Peltier module, were plotted – fig. 3*b*.

■ **Essential tests.** Monolithic diamond dressing was used. The tests were carried out during the dressing of ceramic alumina grinding wheel. The characteristics of the grinding wheel dressing and process parameters are summarized in the table.

To exclude the influence on the results of the study on the changes in the active width of the dresser, the tool with the attrition in the feed direction of a diamond tip equal to 1.1 mm was used. The tests were performed on the grinder for planes SPG 30×80.

TABLE. Principal tests conditions

Grinding wheel profile	Dressing parameters		
	k_d	a_d, mm	Number of jumps/infeed
1 38A 60K VBE 350×127×40	1,5; 3,0	0,01; 0,02	1; 2

Fig. 4 shows two exemplary graphs of thermoelectric reaction of the Peltier module for heat transfer through the stream during dressings performed at different feedrates and depth. Measurement of the series: abrasive/dressing ratio/infeed rate/number of infeed strokes, e.g. 38Ak30a01/×2 means noble electro-corundum/coverage ratio k_d = 3.0, dressing infeed a_d = 0.01/double jump.

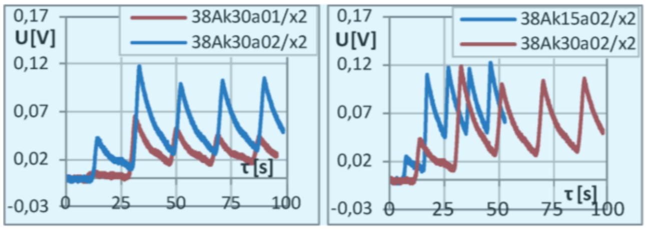

Fig. 4. Thermoelectricity of the Peltier module caused by contact with the dressing products stream

Based on this type of plot and the thermal-voltage characteristics used in the Peltier test, calculations of the heat flux penetrating into the module were made for all tested variants. The heat flux was calculated as a relation of the amount of heat transferred to the module per one overflow and the duration of this transition (7). For the calculations, module's indications acquired during operating in the stable conditions, i.e. 3. to 5. dressing transition, were selected.

$$\dot{Q}_p = \frac{Q_p}{\tau_p} \qquad (7)$$

where: Q_p – heat transferred to the Peltier module; τ_p – duration of the dressing passage.

The results of the calculations are illustrated in the diagrams in fig. 5, while fig. 6 shows graphs, which illustrate calculations referring to the heat flux to the amount of grinding material carried by the flux. It was assumed that the base amount would be the amount of material removed during one dressing passage in the most benign dressing conditions (k_d = 3.0; a_d = 0.01). In the remaining dressing conditions, the amount of this material was 2 times (e.g. k_d = 1.5, a_d = 0.01 or k_d = 3.0, a_d = 0.02) and 4 times (k_d = 1.5; a_d = 0.02) higher.

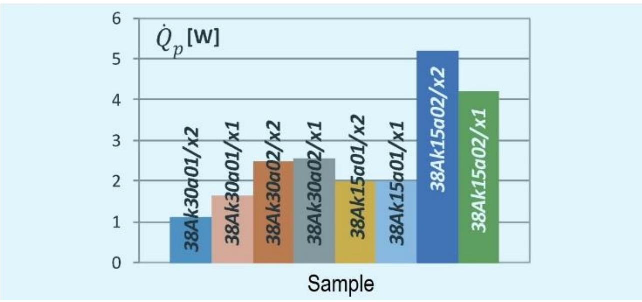

Fig. 5. Absolute value of the heat flux transmitted to the Peltier module

The results shown in the graph (fig. 5) indicate that the heat flux transmitted to the module has a higher value when the dressing takes place with a greater depth of a_d or higher feedrate (k_d is lower) and the heat flux for the same infeed and feedrate has similar values, regardless of the number of jumps to infeed the grinding wheel.

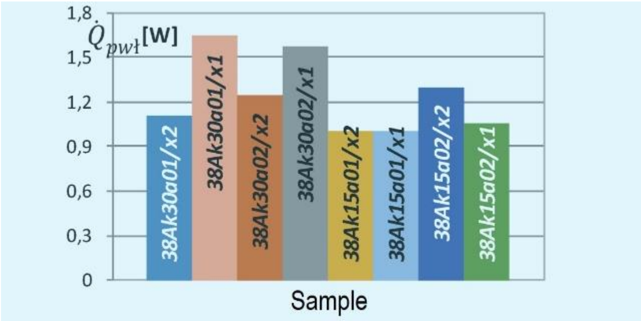

Fig. 6. Heat flow transmitted to the Peltier module relative to the amount of wheel material carried by the stream

In turn, the graph in fig. 6 indicates that lower feedrates and greater depth of dressing contribute to the higher amount of accumulated heat, which is likely to be caused by a higher temperature at the diamond tip contacting with the grinding wheel.

Conclusions

Studies have shown the usefulness of Peltier module to evaluate the enthalpy of stream dressing products. The results indicate a high-resolution method that allows to draw conclusions about the energy aspects of dry dressing process.

The results showed that the enthalpy of grinding wheel particle formation was different in different dressing conditions, therefore it can be stated that the enthalpy reflects the amount of heat generated at the decomposition point of the grinding material by the diamond tip of the dresser and is a useful comparative parameter for these processes.

The absolute values of the heat flux transmitted by the Peltier modulus are small, indicating that the heat dissipation of the grinding wheel particles has a negligible contribution to the energy balance of the dressing process – in the tests, the power consumption associated with the removal of the grinding layer was in the range of 150–400 W.

A more accurate estimation of the enthalpy of the stream requires measurements of the heat that is not transmitted by molecules to the module during their mutual contact. This measurement can be done using the calorimetric method. The measuring device should be equipped with a calorimeter vessel that will gather the stream particles, that contact with the Peltier module.

REFERENCES

1. Linke B., Klocke F. „Temperatures and wear mechanisms in dressing of vitrified bonded grinding wheels". *International Journal of Machine Tools & Manufacture*. 50 (2010): pages 552–558.
2. Rosiak A., Dębkowski R. „Modelowanie rozpraszania ciepła wywiązującego się w procesie cyklicznego obciągania ściernicy z elektrokorundu diamentowym obciągaczem jednoziarnistym". *Mechanik*. 8–9 (2012).
3. Sheiko M. "On calculation of instantaneous temperature on a diamond grit in dressing tool during its operation". Journal of Superhard Materials. 29, 52 (2007): pages 301–306.
4. Tkhagapsoev K. "On wear of diamond in dressing abrasive wheels". Sverkhtverdye Materialy. 2 (1987): pages 30–35.